(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 073 216 A2

EUROPEAN PATENT APPLICATION

(12)

(43) Date of publication:
31.01.2001 Bulletin 2001/05

(51) Int. Cl.[7]: **H04B 7/26**

(21) Application number: **00306065.4**

(22) Date of filing: **17.07.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **28.07.1999 US 362548**

(71) Applicant:
LUCENT TECHNOLOGIES INC.
Murray Hill, New Jersey 07974-0636 (US)

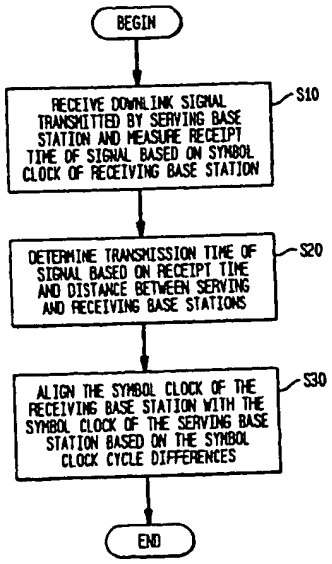
(72) Inventors:
- **McKay, Bernard**
  Morris Plains, New Jersey 07962 (US)
- **Tsai, Sheng-Jen**
  Bridgewater, New Jersey 08807 (US)
- **Falco, Steven A.**
  Morris Plains New Jersey 07950 (US)
- **Matusevich, Alex**
  Morris Plains, New Jersey 07950 (US)
- **Murphy, Myles Patrick**
  Annandale, New Jersey 08801 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Method for synchronizing base stations of a radio communication system

(57) The synchronization system uses a TDMA or AMPS air interface to provide tuning synchronization between previously unsynchronized base stations. The synchronization of base stations is critical between when determining the geographical position of a mobile because the geographical position is determined using a time difference of arrival method. In order to synchronize a remote base station with a serving base station, the remote base station receives a signal from the serving base station and measuring the receiving time of the signal at the remote base station in relation to the clock of the remote base station. The synchronization system determines the transmission time of the signal based on the reception time of the signal and the distance between the base stations, in relation to the clock signal of the second station, and synchronizes the clock of the remote base station to the clock of the serving base station based on the offset in the clock cycles at the time the signal was transmitted.

FIG. 3



EP 1 073 216 A2

FP03-0406
-00EP-NT
'04.10.12
SEARCH REPORT

Printed by Xerox (UK) Business Services
2.16.7 (HRS)/3.6

Description

Field Of The Invention

[0001] The present invention relates to a method for communicating between base stations and mobiles to provide an accurate timing source between unsynchronized base stations and more particularly to a method for communicating between base stations and mobiles to provide an accurate timing source between unsynchronized base stations in a wireless TDMA or AMPS system.

Description Of Related Art

[0002] The increased popularity of wireless telephony including cellular, enhanced specialized mobile radio (ESMR) and personal communication services (PCS), has resulted in a surge in wireless calls to 911. Public safety agencies strive to provide the same level of service to cellular callers as for land line callers, but they are hampered by significant technological diversity. Enhanced 911 systems were designed and constructed to support land lines telephones. Land lines telephones are connected via fixed wires back to Telco Central Offices (TCOs), and thus there is a permanent relationship between the telephone and its location. When someone places a 911 call from a land line telephone, the location of the phone is used to determine the closest police, fire, medical agency and public safety answering point (PSAP). Having this detailed operation at the operator's fingertips enables the rapid response for which 911 systems are known.

[0003] However, wireless callers are not associated with any location, which is why they are so popular. This benefits works against a wireless telephone or mobile use that requires emergency assistance. When a caller's geographic location is unknown, a operator must spend valuable time at the start of the call obtaining basic information about the location and area police, fire, medical agencies and PSAPs before fully understanding the nature of the emergency. Therefore, a quick determination of a caller's location can be crucial for a person's safety.

[0004] Wireless telephone base stations with mobile location systems are being considered to determine the geolocation of a mobile. Since the advent of radar, high accuracy location systems have used time difference of arrival (TDOA) methods as a preferred technology for location determination. In fact, the Global Positioning System (GPS) is a TDOA based system as are most of the systems proposed for the location and monitoring service being allocated by the FCC. TDOA systems operate by placing location receivers at multiple base stations geographically disbursed in a wide area. When a signal is transmitted from a mobile, the signal propagates at approximately a thousand feet per second to local base stations, where the signal reception is time stamped. The differences in time stamps are then compared using well known triangulation methods to produce intersecting hyperbolic lines from which the location is estimated.

[0005] However, TDOA methods require the base stations used in the triangulation methods to be accurately aligned in time. In other words, the base stations must be synchronized. Currently in TDMA and AMPS wireless systems, external equipment must be added to all of the individual base stations to provide the required timing accuracy and synchronization.

[0006] CDMA is a very different technology than TDMA or AMPS. CDMA has an N=1 frequency reuse plan where the same frequency spectrum is used by neighbor cells (to increase capacity). The synchronization of CDMA cells allows digitally coded voice data to be seamlessly handed off to a neighbor cell. TDMA has an N=7 frequency reuse plan and the individual 30 kHz frequency channels are not reused by adjacent cells but reused by cells far enough away to minimize co-channel interference.

[0007] Therefore, it is desirable to provide a method to provide timing synchronization between base stations in TDMA and AMPS systems without the implementation of expensive external equipment.

Summary Of The Invention

[0008] The present invention improves upon conventional TDMA and AMPS systems by providing an approach to use a TDMA/AMPS air interface to provide timing synchronization between unsynchronized base stations. This is accomplished in a preferred embodiment by marking time stamps of signals arriving at predetermined or candidate base stations from a serving base station. The time stamps are marked in relation to a clock signal of the respective candidate base station. The respective candidate base station becomes synchronized with the serving base station based on a down link offset calculated at each candidate base station that represents the fractional symbol time, relative to the internal symbol clock of the respective candidate base station, between the time the signal is transmitted from the serving base station to a next predetermined cyclical point of the symbol clock of the candidate base station. The predetermined cyclical point may be, for example, at the beginning of the next cycle when clock goes high. The respective candidate base station determines the time the signal was transmitted based on the time the signal is received at the candidate base station and the known time required for the signal to travel from the serving base station to the candidate base station.

[0009] Since the serving base station transmits the signal at a known point of its symbol clock cycle, for example the beginning of a clock cycle, the candidate base station can synchronize its internal symbol clock to the internal symbol clock of the serving base station. The synchronization is established by aligning the cal-

BNSDOCID: <EP 1073216A2 I >

culated down link symbol offset to correspond to the signal transmission time at the serving base station.

[0010] Although the internal symbol clocks of the base stations are not synchronized, they do operate at the same frequency based on the accurate and conventional T1 link clock. In other words, each clock operates at a frequency of about 1.544 MHz plus or minus 75 Hz. Accordingly, base station symbol clocks maintain approximately the same relationship in alignment to other base station symbol clocks. Therefore, two base stations that are in sync will remain synchronized for subsequent communication. When base stations are in sync, it is possible to perform operations that require synchronized stations, such as TDOA information used for determining the location of a mobile. Therefore, this invention provides a method for synchronizing base stations such that a mobile's location can be determined using conventional TDOA methods.

[0011] Determining a mobile's position provides a greater benefit than the application of emergency management from 911 calls. Other applications, such as fraud management, location sensitive billing, vehicle and fleet management, inventory/package monitoring, and wireless system design would also become available to TDMA and AMPS systems without severe hardware implementation costs.

[0012] In a preferred embodiment, the synchronization system is a software implementation on a computer used to determine the geographic location of the mobile. The software implementation receives a time stamp of receipt of a first signal transmitted from the serving base station to a candidate base station. The time stamp is measured in relation to the symbol clock of the candidate base station. The synchronization system determines the time the signal was transmitted from the serving base station, as a transmission time stamp, based on the receiving time stamp of the signal and the known distance between the serving base station and candidate base station. This transmission time stamp is measured in relation to the symbol clock of the candidate base station. The synchronization system then synchronizes the symbol clock of the candidate base station to the symbol clock of the serving base station by aligning the determined transmission time stamp of the signal to the known point of the serving base station symbol clock cycle that represents the actual transmission time stamp from the serving base station.

Brief Description Of The Drawings

[0013] The invention will be described in detail with reference to the following drawings, wherein like numerals represent like elements and:

Fig. 1 is a block diagram illustrating the basic components of a conventional TDMA/AMPS wireless system;

Fig. 2(a) is a schematic perspective view of the synchronization system implementation according to a preferred embodiment of the invention;

Fig. 2(b) is a schematic perspective view of the synchronization system implementation according to another preferred embodiment of the invention;

Fig. 3 illustrates a flow chart of a preferred embodiment of the synchronization system;

Fig. 4 is a timing chart illustrating an example synchronization of internal symbol clocks from different base stations in accordance with a preferred embodiment of the invention;

Fig. 5 illustrates a flow chart of another preferred embodiment of the synchronization system; and

Fig. 6 illustrates a flow chart of yet another preferred embodiment of the synchronization system.

Figs. 7(a) and 7(b) illustrate an exemplary message format in a preferred embodiment of the synchronization system.

Detailed Description Of The Invention

[0014] The present invention is directed to a synchronization system for a method of using a TDMA air interface to provide timing synchronization between base stations involved with a mobile locate without the use of expensive external base station equipment. The system and method support TDMA and AMPS communication systems and meets current distance and response time requirements of 911 using existing base station hardware. Although the embodiments described herein are used in a TDMA communication system, it is understood that the embodiment are also applicable to an AMPS communication system as described below.

[0015] One embodiment of the approach for synchronizing a communication station to another communication station is shown, for example, at Fig. 1. As shown, Fig. 1 illustrates a conventional TDMA wireless system 5 including a serving base station 10, a candidate base station 20, a candidate base station 30, and a mobile 40. The serving base station 10 is separated from the candidate base station 20 by a known distance D_{sa}, and is separated from the candidate base station 30 by the known distance D_{sb}. The mobile 40 is located between the base stations 10, 20 and 30 and communicates with the base stations 10, 20 and 30 via communication channels over which signals modulated with data and codes are transmitted.

[0016] Fig. 2(a) illustrates a diagram of a synchronization system implementation. The synchronization system 1 includes a computer 60, an article of manufacture 70 and is preferably located at the serving base sta-

BNSDOCID: <EP_____1073216A2_I_>

tion 10 or at another location that can communicate in real-time with a receiver or transmitter of the serving base station 10. Therefore, the synchronization system 1 may be located at one of the candidate base stations 20, 30 or another location communicatively connected to the serving base station 10. The article of manufacture 70 includes a computer-readable medium and an executable program for synchronizing the candidate base stations 20, 30 to the serving base station 10 and for locating the mobile 40.

[0017] Fig. 2(b) illustrates an alternative synchronization system implementation. The synchronization system 1 includes the computer 60 for receiving a signal 80 carrying the executable program for synchronizing the candidate base stations 20, 30 to the serving base station 10. The signal 80 is transmitted in a digital format either with or without a carrier wave.

[0018] Preferred embodiments of the invention will be described in the following order. First, an approach to synchronize a candidate base station 20, 30 to the serving base station 10 will be explained while referring to Figs. 3 and 4. Then, an approach for measuring the time between a transmission event from the serving base station 10 and receipt of a subsequent event will be explained while referring to Figs. 4 and 5. Last, an approach for gathering time differences for different candidate base stations 20, 30 for locating the mobile 40 will be explained while referring to Figs 4 and 6.

[0019] Fig. 3 illustrates a flow chart for synchronizing a candidate base station 20, 30 to a serving base station 10 from the perspective of the respective candidate base station 20, 30. The serving base station 10 sends a down link "event" with a time stamp embedded in unused data symbols of the frame. The "event" for TDMA is, for example, a point in time when a phase change occurs between symbols in the transmit. At S10, the candidate base station 20, 30 receives the down link event and measures the time stamp embedded in the "event". The candidate base station 20, 30 measures the receipt time based on the symbol clock of the respective candidate base station 20, 30.

[0020] Fig. 4 illustrates an example timing chart of an internal symbol clock of the serving base station 10 and a candidate base station 20, 30. As shown, the serving base station 10 transmits the down link "event" at transmission time T_0, which is received at the candidate base station 20, 30 at the down link reception time T_1, as described in step S10 of Fig. 3. The receiving time of the down link "event" reception time T_1 is shown at Fig. 4 relative to the symbol clock of the respective candidate base station 20, 30.

[0021] At step S20 of Fig. 3, the synchronization system 1 determines the transmission time T_0 of the down link "event" in relation to the symbol clock of the candidate base station 20, 30. The down link transmission time T_0 is determined based on the time T_1 that the transmission is received at the candidate base station 20, 30, and the known distance between the serving base station 10 and the respective receiving base station 20, 30. In other words, the down link transmission time T_0 is equal to the down link reception time T_1, minus the time for the down link signal to travel from the serving base station 10 to the candidate base station 20, 30. Assuming a line of sight signal path, the travel time of the signal is equal to the distance between the serving and candidate base stations divided by the wavespeed of the signal.

[0022] At step S30 of Fig. 3 the synchronization system 1 aligns the symbol clock of the candidate base station 20, 30 to the serving base station 10 according to the symbol clock differences. The serving base station 10 transmits its down link "event" at time T_0, for example, when a phase change occurs between symbols in the transit. As shown at Fig. 4, the transmission time T_0 for the phase change occurs when the symbol clock goes high. The down link transmission time T_0 determined by the candidate base station 10 is marked on the symbol clock of the candidate base station 20, 30, and is aligned with the known point in time when the serving base station 10 sends the down link "event". The synchronization system 1 determines a down link offset D_0 as the time between the transmission time T_0 and the beginning of a next symbol clock cycle at the candidate base station 20, 30. Accordingly, the down link offset D_0 represents the symbol offset between the clocks of the serving base station 10 and the respective candidate base station 20, 30.

[0023] Thus the symbol clock of the candidate base station 20, 30 is synchronized with the symbol clock of the serving base station 10 because any point on the symbol clock of the serving base station 10 corresponds to a similar point on the symbol clock of the candidate base station 20,30 shifted by the down link offset D_0. Accordingly, by aligning the predetermined time of the symbol clock at the serving base station 10 with the calculated down link transmission time T_0 the candidate base station 20, 30 is synchronized with the serving base station 10.

[0024] Next, an approach for measuring the time between a transmission event from the serving base station 10 and receipt of a subsequent event will be explained with references to Figs. 4 and 5. Once the candidate base station 20 or 30 is synchronized with the serving base station 10 based on the down link offset D_0, subsequent "events" are also synchronized. That is, a subsequent time stamp received at the candidate base station 20, 30 can be measured from a known point on the symbol clock of the serving base station 10. Therefore, a subsequent signal can be received by the candidate base station 20, 30, and the synchronization system can determine a time difference between the time of the transmission down link T_0 and the receipt of the subsequent signal.

[0025] Fig. 5 illustrates an example flow chart of another preferred embodiment of synchronization system 1. In this preferred embodiment, at step S100, the

EPODOC: EP 1073216A2 1 -

synchronization system 1 synchronizes a receiving base station 20, 30 to a serving base station 10 as discussed above and shown at Fig. 3 for steps S10, S20 and S30. After the synchronization system 1 synchronizes the candidate base station 20, 30, the respective candidate base station 20, 30 receives a subsequent signal at step S110. This subsequent signal can originate from any transmitting source, such as the mobile 40, the serving base station 10, or another candidate base station 20, 30. The candidate base station 20, 30 measures the receipt time of the subsequent signal in relation to the symbol clock of the receiving candidate base station 20, 30.

[0026] After the candidate base station 20, 30 receives a down link message from the serving base station 10 and synchronizes the respective candidate base stations 20, 30 to the serving base station 10, at S100, a transmitting source such as the mobile 40 sends an uplink "event" in response to the control message. The uplink "event" is, for example, a phase change that occurs between known symbols in the transmit. The serving base station 10 and candidate base stations 20, 30 receive the uplink "event" and measure the receipt time of the uplink "event" based on the symbol clock of the respective base station 10, 20 and 30. Since the candidate base stations 20, 30 have been synchronized with the serving base station 10 at step S100, the synchronization system 1 can determine at step S120 a difference between the transmission time T_0 of the down link "event" transmitted from the serving base station 10 and the receipt time T_4 of the uplink "event" transmitted from the mobile 40 and received at the respective candidate station 20, 30. Of course, the synchronization system 1 can also determine at step S120 the difference between the transmission time T_0 of the down link "event" transmitted from the serving base station 10 and the receipt time T_5 of the uplink "event" transmitted from the mobile 40 and received back at the serving base station 10. The difference in time is reported as the sum of the down link offset D_0 - the time from time T_0 to the beginning or rise time of the next symbol - plus an uplink offset U_0, described below, plus the number of symbols between the down link offset D_0 and the uplink offset U_0.

[0027] Fig. 4 also illustrates an example uplink offset U_0 of an uplink "event" received by a candidate base station 20, 30. As discussed above, at step S110 of Fig. 5, the candidate base station 20, 30 receives the uplink "event" at T_4 in relation to the candidate symbol clock. The synchronization system 1 then measures the time interval between T_4 and the most recent rise time of the symbol clock, time T_3. The uplink offset U_0 is then determined as the fractional part of a symbol clock relative to the internal symbol clock of the respective candidate base station 20, 30 from the beginning of the last symbol clock rise time T_3 to the uplink "event" receipt T_4. Therefore, the synchronization system 1 measures the total time between the transmission time T_0 of a down link "event" from the serving base station 10 to the receipt time of an uplink "event" received at the candidate base station 20, 30 as the sum of the down link offset D_0, the uplink offset U_0 and the number of symbols therebetween.

[0028] Next, an approach for gathering time differences from different candidate base stations 20, 30 for locating the mobile 40 will be explained with reference to Figs. 4 and 6. The embodiment describes a method for providing an accurate timing source for locating a geographic position of a mobile 40 placing a 911 call.

[0029] At step S200 of Fig. 6, the serving base station 10 receives a "911" call. The call is transmitted by the mobile 40 on a reverse channel and triggers the base station 10 to locate the mobile 40, for example as discussed below. In response to the 911 call, the serving base station 10 transmits a geo-locate request to neighboring base stations local to the serving base station 10. The geo-locate request is embedded in T1 control messages and is transmitted via an executive control processor (ECP) at the switch in the PSTN.

[0030] Based on the geo-locate request, the neighboring base stations check the signal quality of the transmit signal sent from the mobile 40, and sends the signal quality level back to the serving base station 10 through the ECP. Upon receipt of the resulting signals, at step S220, the serving base station 10 determines which neighboring base stations are good candidates for a geo-location of the mobile 40. The neighboring base stations that received the transmit signals from the mobile 40 with a signal quality that is sufficiently high are assigned to be candidate base stations 20, 30 and are used to gather TDOA information, as described below.

[0031] At step S230, the serving base station transmits a down link message to the mobile that is also received by the candidate base stations 20, 30. In a preferred embodiment, as illustrated in Figures 7(a) and 7(b), an IS 136A message format is utilized. Figure 7(a) illustrates the slot format for mobile station to base station messaging and Figure 7(b) illustrates the slot format for base station to mobile station messaging. Slot G represents guard time, slot R represents ramp time, DATA represents user information or FACCH, SACCH represents slow associated control channel, CDVCC represents coded digital verification color code, SYNC represents synchronization in training, CDL represents coded digital control channel locator, and RSVD represent reserved. In the present embodiment, commands can be sent during the SACCH interval of the down linked message.

[0032] The candidate base stations 20, 30 then synchronize their internal symbol clock with the internal symbol clock of the serving base station 10 in the manner described above at steps S10 to S30 of Fig. 3.

[0033] The down link message also informs the respective candidate base stations 20, 30 that the serving base station 10 will transmit a control message to

BNSDOCID: <EP_____1073216A2_I_>

the mobile 40. That is, embedded in the down link message is an instruction informing the candidate base stations 20, 30 that the serving base station 10 will transmit a control message to the mobile 40 at a specific time, such as a number of symbol clock cycles from the transmission of the down link message transmitted to the candidate base station 20, 30. For example, embedded in the down link message is an instruction informing the candidate base station 20, 30 that the serving base station 10 will transmit a control message to the mobile 40 at time T_m, as shown in Fig. 4.

[0034] The candidate base stations 20, 30, which have been synchronized with the serving base station 10, count down to the specific time that the down link message indicates as when the serving base station 10 will transmit the mobile control message, and then starts counting from that specific time T_m. At step S240 of Fig. 6, the serving base station 10 transmits the mobile control message. The mobile control message instructs the mobile 40 to transmit an uplink "event" which, for example as described above, is a symbol phase change occurrence in TDMA. Accordingly, the mobile 40 receives the mobile control message from the serving base station 10 and transmits a reply uplink "event" to the base stations 10, 20 and 30. At step S250, the base stations 10, 20, 30 receive the reply uplink "event" and measure the receipt time of the reply uplink "event" in a manner similar to step S110 described above for Fig. 5.

[0035] At step S260 of Fig. 6, the base stations 10, 20 and 30 determine the time difference between the transmission time of the mobile control message sent from the serving base station 10 and the receipt time of the mobile 40 uplink "event" received at the respective base station 10, 20 and 30. The differences for the candidate base stations 20 and 30 are determined in a manner similar to the approach discussed above for step S120 in Fig. 5. In this embodiment, the difference between the transition time of the mobile control message from the serving base station 10 and the receipt time of the mobile uplink "event" is determined as the sum of the down link offset D_0, the uplink offset U_0 and the number of integer symbol counts at the respective serving base station 20 and 30 that have transpired between the time T_m and the uplink offset U_0.

[0036] It is understood that this time difference should not include delays that are unique to each base station 20, 30. These delays include a group delay of the candidate base station 20 and 30 receiver path, and a delay due to the distance between the serving base station 10 and the candidate base station 20 and 30. However, both these delays are known or can readily be determined. The group delay is the delay of the signal as it passes through base station receiver circuitry, base station transmit circuitry, or mobile receive or transmit circuitry. The group delay is a constant value but must be measured for each base station. The delay between the base station and the candidate base station is due to the distance that the RF signal travels, in nanosecond per foot.

[0037] The time difference between the transmission time of a signal from the serving base station 10 and the receipt time of the mobile 40 uplink "event" at the serving base station 10 is determined in a manner similar to the approaches discussed above at steps S120 and S260 for the candidate base stations 20 and 30. However, because the serving base station 10 is synchronized with itself, and its down link "event" and mobile control message are transmitted from the serving base station 10 at the beginning of a symbol clock cycle, there is no down link offset D_0. Therefore, the time difference at step S260 for the serving base station 10 is equal to the sum of the number of integer internal symbol counts at the serving base station 10 that have transpired between the transmission of the mobile control message at time T_m and receipt of the uplink "event" at time T_5, and the uplink offset U_0 which is the fractional part of a symbol time from the previous whole symbol to the uplink "event", receipt time T_5.

[0038] As described above for the candidate base stations 20 and 30, known group delays are then subtracted from the sum to arrive at a time difference consistent with the time difference as determined for the candidate base stations 20 and 30. For the serving base station 10, the delays include a group delay of the receiver at the serving base station 10 from the actual time of receipt of the uplink "event" at the receiver to the recording time of the time stamp. Another delay at the serving base station 10 is the transmitter group delay measured as the difference in time between receipt of an instruction to transmit a signal and the actual time of the transmission. As noted above, these counts are known or can be readily determined.

[0039] As shown in Fig. 6, after the time differences between the transmission time T_4 the mobile control message and the receipt time T_m of the mobile uplink "event" are determined at step S260, the candidate base stations 20 and 30 transmit the time differences to the serving base station 10. At step S270, the serving base station 10 receives the time differences from the candidate base stations 20, 30. At step S280, a computer located, for example, at the serving base station 10 uses TDOA to determine the position of the mobile 40 based on the time differences. The TDOA technology used to determine the position of the mobile 40 is well known and is based on the difference in time between when the base stations 10, 20 and 30 receive the uplink "event".

[0040] It is also understood that a delay exist in the mobile 40 between when the mobile 40 receives the mobile control message and when the mobile 40 transmits the "event". However, this mobile delay is identical for each of the determined time differences, and is therefore cancelled out where the time differences from one of the base stations 10, 20 and 30 are compared to another of the base stations 10, 20 and 30.

[0041] The above embodiments are described in relation to a TDMA system. For an AMPS system, the approach is basically identical. The relevant difference between the approaches is that the uplink "event" transmitted by the mobile 40 is an AMPS event instead of a TDMA event. Accordingly, the uplink "event" is measured by, for example, receipt of a mobile identification number included in the uplink signal. The mobile identification number is located at a predetermined point in the transmission string of the "event" data transmitted on the reverse channel.

[0042] While this invention has been described in connection with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the scope of the invention as defined in the following claims.

Claims

1. A method for synchronizing a first station and a second station, comprising:

   (a) receiving a first signal from the first station, the first station having a clock signal unsynchronized with a clock signal of the second station;

   (b) measuring a receiving time of the first signal in relation to the clock signal of the second station;

   (c) determining a transmission time of the first signal based on the measured receiving time of the first signal and a distance between the first station and the second station, in relation to the clock signal of the second station; and

   (d) synchronizing the clock signal of the second station to the clock signal of the first station based on a signal cycle difference between the clock signals at the transmission time.

2. The method of claim 1, further comprising:

   (e) receiving a second signal;

   (f) measuring a receiving time of the second signal in relation to the clock signal of the second station; and

   (g) determining the difference between the transmission time of the first signal and the receiving time of the second signal.

3. The method of claim 2, wherein the second signal is received from a source other than the first station.

4. The method of claim 1, further comprising:

   (e) measuring a predetermined time based on the first signal in relation to the clock signal of the second station;

   (f) receiving a second signal;

   (g) measuring a receiving time of the second signal in relation to the clock signal of the second station; and

   (h) determining a difference between the predetermined time and the receiving time of the second signal.

5. The method of claim 4, wherein the predetermined time is indicative of a time when the first station transmits a control message.

6. The method of claim 4, wherein the second signal is received from a source other than the first station.

7. A method for synchronizing a first station and a plurality of second stations, comprising:

   (a) transmitting a down link message to the second stations to synchronize a symbol clock of each of the second stations to a symbol clock of the first station;

   (b) transmitting a control message to the mobile at a predetermined time, the control message requesting a reply message from the mobile;

   (c) receiving the reply message from the mobile and measuring a time that the reply message was received at the first station as a first station receiving time;

   (d) determining a difference between the predetermined time and the first station receiving time as a first station time difference; and

   (e) receiving messages from the second stations representing a difference between the predetermined time and a time that the reply message was received at each second station as a plurality of second station time differences, so a location of the mobile can be determined.

8. The method of claim 7, prior to step (a), further comprising:

BNSDOCID: <EP_____1073216A2_I_>

(x) transmitting a request message to a plurality of nearby stations to determine a strength of a signal originating from a mobile;

(y) receiving response messages from the nearby stations indicating the strength of the signal originating from the mobile; and

(z) determining the nearby stations having the strength greater than a predetermined amount as the second stations.

9. The method of claim 7, prior to step (a), further comprising:

(z) receiving one of a 911 call and a mobile locate call as a mobile locate request,
wherein step (a) transmits the down link message to the second stations based on the mobile locate request.

10. The method of claim 7, wherein the down link message informs the second station of the predetermined time when the control message is transmitted.

11. A synchronization system implemented on a computer, comprising:

means for receiving a first signal from the first station, the first station having a clock signal unsynchronized with a clock signal of the second station;

means for measuring a receiving time of the first signal in relation to the clock signal of the second station;

means for determining a transmission time of the first signal based on the measured receiving time of the first signal and a distance between the first station and the second station, in relation to the clock signal of the second station; and

means for synchronizing the clock signal of the second station to the clock signal of the first station based on a signal cycle difference between the clock signals at the transmission time.

12. The synchronization system of claim 11, further comprising:

subsequent means for receiving a second signal;

subsequent means for measuring a receiving time of the second signal in relation to the clock signal of the second station; and

subsequent means for determining the difference between the transmission time of the first signal and the receiving time of the second signal.

13. The synchronization system of claim 11, wherein the second signal is received from a source other than the first station.

14. The synchronization system of claim 11, further comprising:

first subsequent means for measuring a predetermined time based on the first signal in relation to the clock signal of the second station;

subsequent means for receiving a second signal;

second subsequent means for measuring a receiving time of the second signal in relation to the clock signal of the second station; and

subsequent means for determining a difference between the predetermined time and the receiving time of the second signal.

15. The synchronization system of claim 14, wherein the predetermined time is indicative of a time when the first station transmits a control message.

16. An executable program embodied on a computer-readable medium for synchronizing a first station and a second station, comprising:

a receiving source code segment for receiving a first signal from the first station, the first station having a clock signal unsynchronized with a clock signal of the second station;

a measuring source code segment for measuring a receiving time of the first signal in relation to the clock signal of the second station;

a determining source code segment for determining a transmission time of the first signal based on the measured receiving time of the first signal and a distance between the first station and the second station, in relation to the clock signal of the second station; and

a synchronizing source code segment for synchronizing the clock signal of the second station to the clock signal of the first station based on a signal cycle difference between the clock

EPODOC: EP 1073216A2

signals at the transmission time.

17. A computer data signal, comprising:

a receiving signal segment for receiving a first signal from the first station, the first station having a clock signal unsynchronized with a clock signal of the second station;

a measuring signal segment for measuring a receiving time of the first signal in relation to the clock signal of the second station;

a determining signal segment for determining a transmission time of the first signal based on the measured receiving time of the first signal and a distance between the first station and the second station, in relation to the clock signal of the second station; and

a synchronizing signal segment for synchronizing the clock signal of the second station to the clock signal of the first station based on a signal cycle difference between the clock signals at the transmission time.

BNSDOCID: <EP_____1073216A2_I_>

FIG. 1

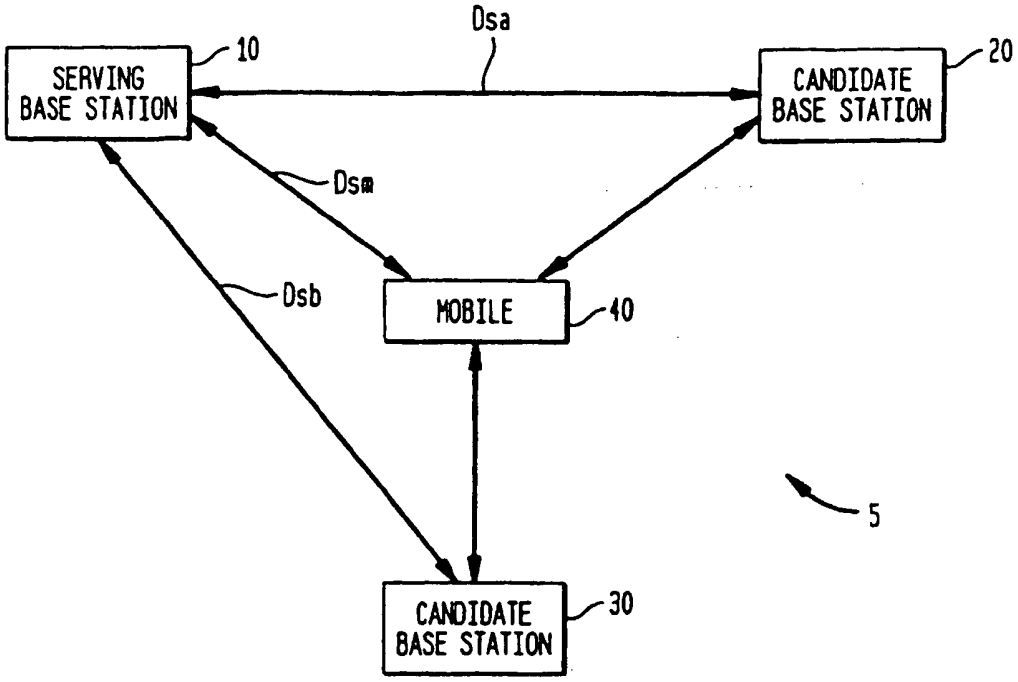


FIG. 2A

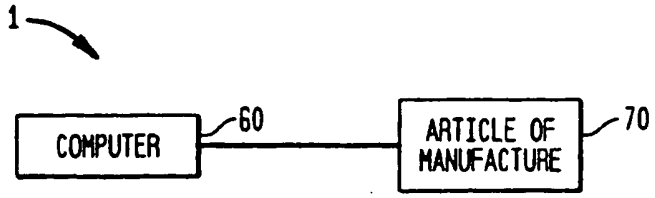


FIG. 2B

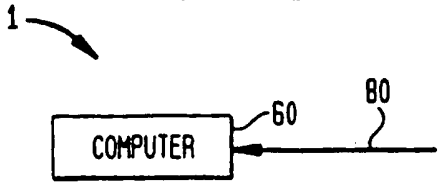
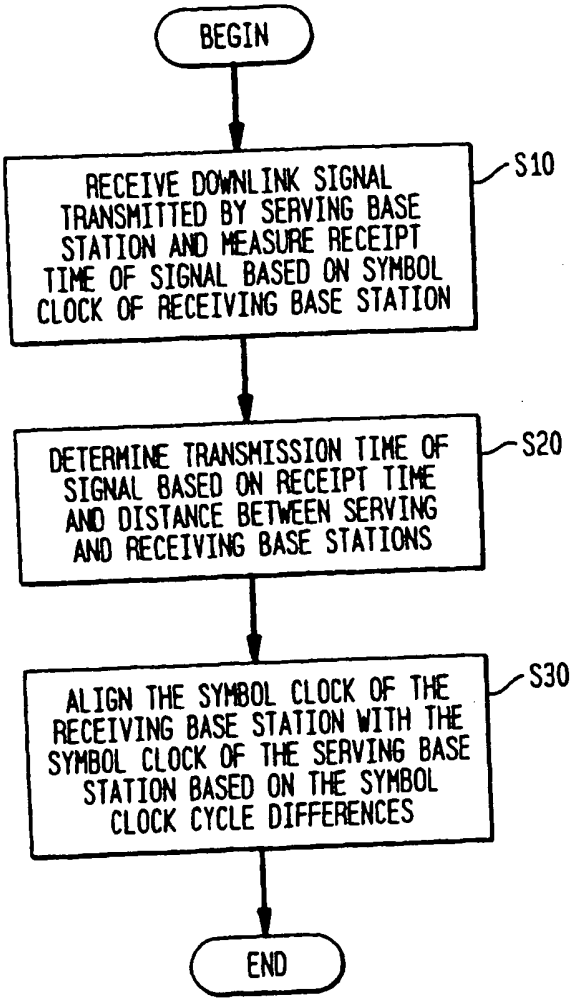
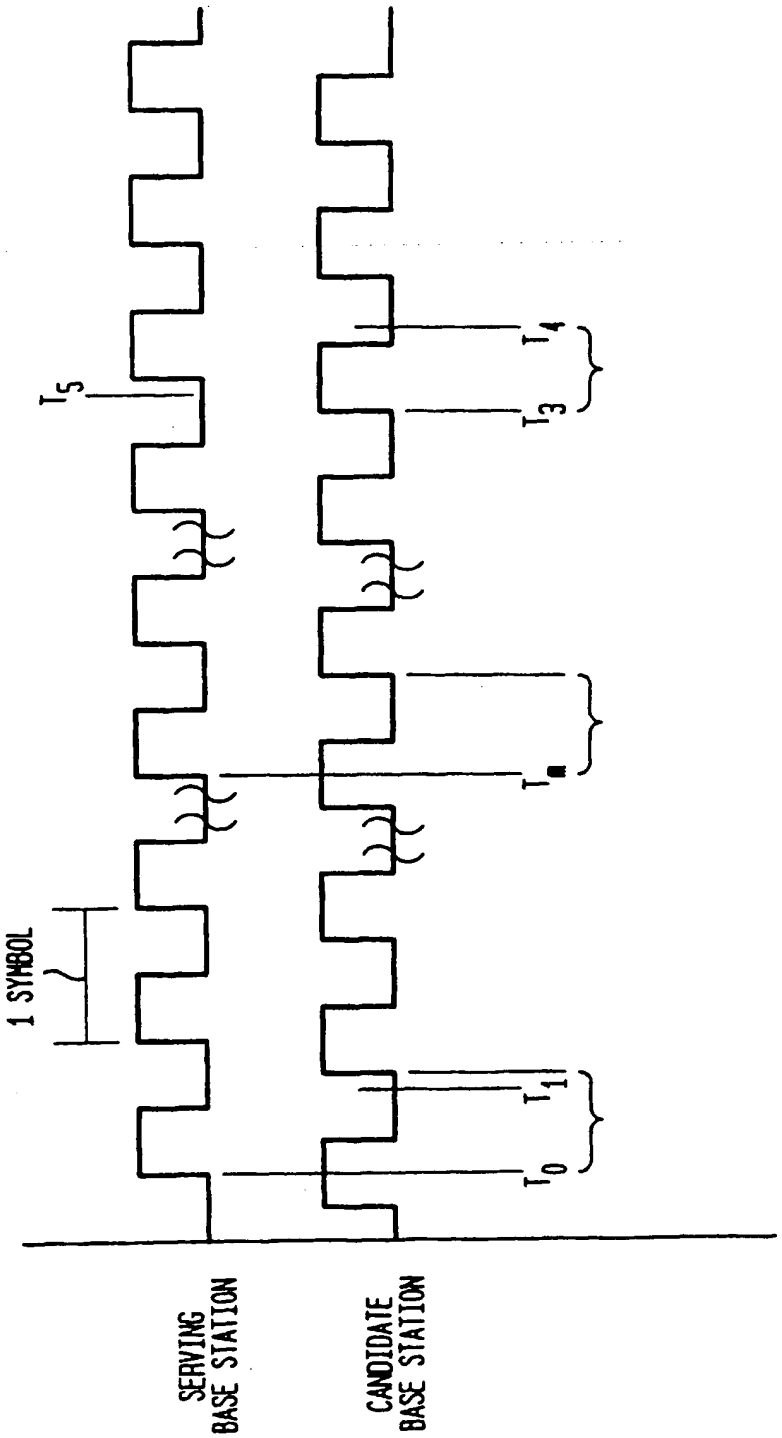


FIG. 3



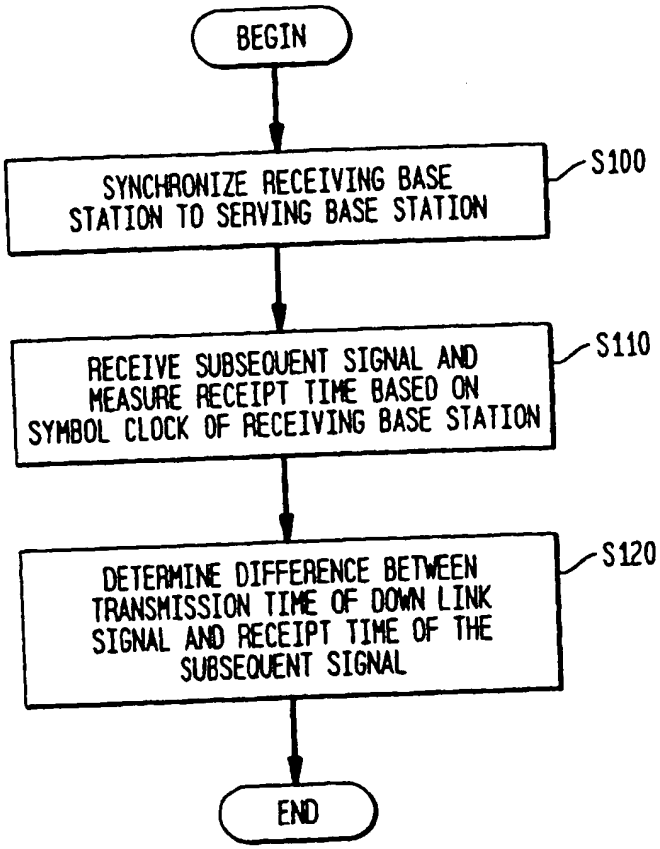
BNSDOCID: <EP_____1073216A2_I_>

FIG. 4



BNSDOCID: <EP 1073216A2 I >

FIG. 5



BNSDOCID: <EP_____1073216A2_I_>

FIG. 6

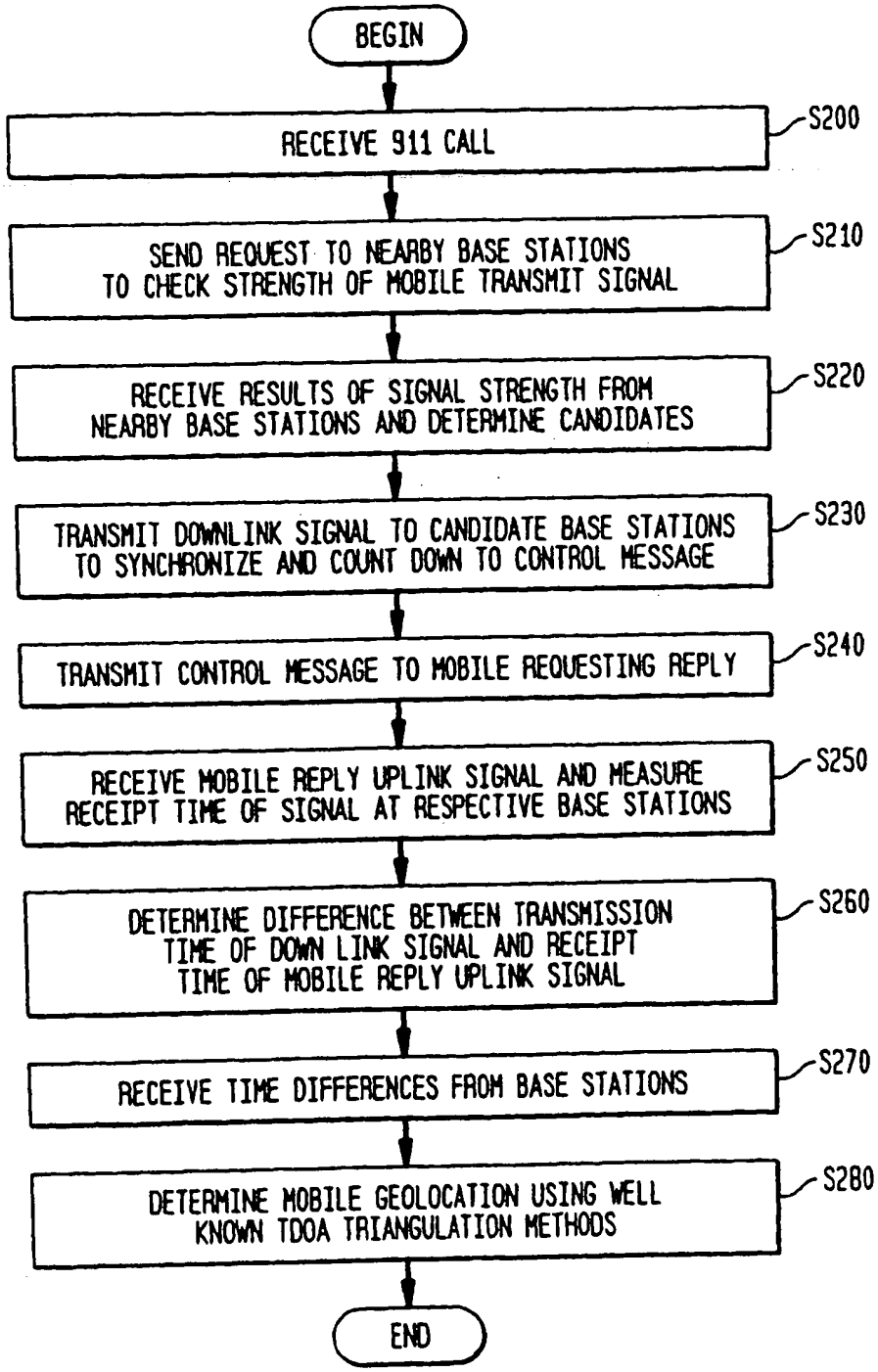

BEGIN
RECEIVE 911 CALL
S200
SEND REQUEST TO NEARBY BASE STATIONS TO CHECK STRENGTH OF MOBILE TRANSMIT SIGNAL
S210
RECEIVE RESULTS OF SIGNAL STRENGTH FROM NEARBY BASE STATIONS AND DETERMINE CANDIDATES
S220
TRANSMIT DOWNLINK SIGNAL TO CANDIDATE BASE STATIONS TO SYNCHRONIZE AND COUNT DOWN TO CONTROL MESSAGE
S230
TRANSMIT CONTROL MESSAGE TO MOBILE REQUESTING REPLY
S240
RECEIVE MOBILE REPLY UPLINK SIGNAL AND MEASURE RECEIPT TIME OF SIGNAL AT RESPECTIVE BASE STATIONS
S250
DETERMINE DIFFERENCE BETWEEN TRANSMISSION TIME OF DOWN LINK SIGNAL AND RECEIPT TIME OF MOBILE REPLY UPLINK SIGNAL
S260
RECEIVE TIME DIFFERENCES FROM BASE STATIONS
S270
DETERMINE MOBILE GEOLOCATION USING WELL KNOWN TDOA TRIANGULATION METHODS
S280
END

FIG. 7A

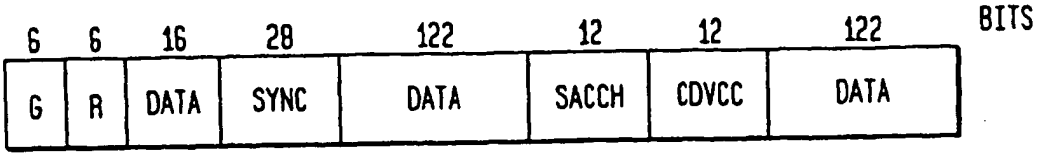
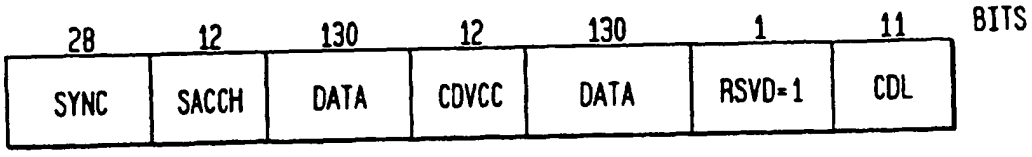


FIG. 7B



BNSDOCID: <EP_____1073216A2_I_>

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 073 216 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
02.05.2002 Bulletin 2002/18

(51) Int Cl.7: H04B 7/26

(43) Date of publication A2:
31.01.2001 Bulletin 2001/05

(21) Application number: 00306065.4

(22) Date of filing: 17.07.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 28.07.1999 US 362548

(71) Applicant: LUCENT TECHNOLOGIES INC.
Murray Hill, New Jersey 07974-0636 (US)

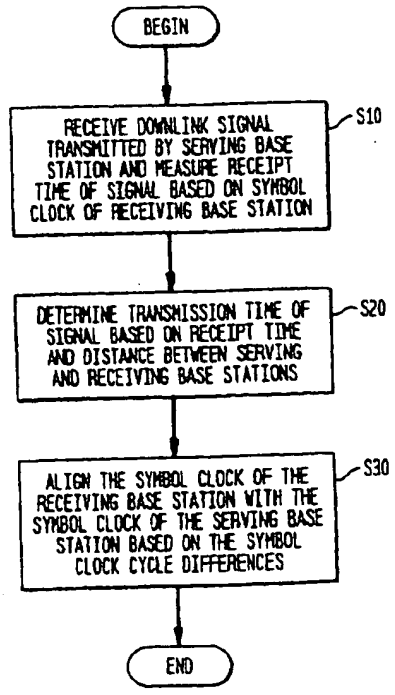
(72) Inventors:
- McKay, Bernard
Morris Plains, New Jersey 07962 (US)
- Tsai, Sheng-Jen
Bridgewater, New Jersey 08807 (US)
- Falco, Steven A.
Morris Plains New Jersey 07950 (US)
- Matusevich, Alex
Morris Plains, New Jersey 07950 (US)
- Murphy, Myles Patrick
Annandale, New Jersey 08801 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Method for synchronizing base stations of a radio communication system

(57) The synchronization system uses a TDMA or AMPS air interface to provide tuning synchronization between previously unsynchronized base stations. The synchronization of base stations is critical between when determining the geographical position of a mobile because the geographical position is determined using a time difference of arrival method. In order to synchronize a remote base station with a serving base station, the remote base station receives a signal from the serving base station and measuring the receiving time of the signal at the remote base station in relation to the clock of the remote base station. The synchronization system determines the transmission time of the signal based on the reception time of the signal and the distance between the base stations, in relation to the clock signal of the second station, and synchronizes the clock of the remote base station to the clock of the serving base station based on the offset in the clock cycles at the time the signal was transmitted.

FIG. 3



EP 1 073 216 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 6065

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	LAGRANGE ET AL: "Autonomous inter base station synchronisation via a common broadcast control channel" VEHICULAR TECHNOLOGY CONFERENCE, 1994 IEEE 44TH STOCKHOLM, SWEDEN 8-10 JUNE 1994, NEW YORK, NY, USA,IEEE, 8 June 1994 (1994-06-08), pages 1050-1054, XP010123236 ISBN: 0-7803-1927-3 * page 1051, right-hand column, line 1 - page 1052, right-hand column, line 10 * * page 1052, right-hand column, line 11 - line 32 * * figure 1 *	1,11,16, 17	H04B7/26
X	WO 98 52376 A (NOKIA TELECOMMUNICATIONS OY ;RANTALAINEN TIMO (FI); SILVENTOINEN M) 19 November 1998 (1998-11-19) * page 3, line 35 - page 5, line 36 * * page 1, line 21 - line 34 * * figure 1 *	1,11,16, 17	
P,X	WO 99 57826 A (NOKIA TELECOMMUNICATIONS OY ;ESSER ALEX (FI); WESBY PHILIP (FI)) 11 November 1999 (1999-11-11) * page 8, line 24 - page 11, line 1 * * page 11, line 32 - page 15, line 18 *	1,11,16, 17	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04B H04L H04J H04Q
A	EP 0 767 594 A (NOKIA MOBILE PHONES LTD) 9 April 1997 (1997-04-09) * column 4, line 29 - column 5, line 40 *	7-10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 February 2002	Larcinese, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

BNSDOCID: <EP 1073216A3 I >

European Patent Office

Application Number
EP 00 30 6065

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

BNSDOCID: <EP_____1073216A3_I_>

European Patent Office

LACK OF UNITY OF INVENTION
SHEET B

Application Numb
EP 00 30 6065

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-6,11-17

   Method, system and computer program for synchronizing a first station with a second station.

2. Claims: 7-10

   Method for determining the location of a mobile station.

BNSDOCID: <EP 1073216A3 I >

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 6065

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-02-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9852376 A	19-11-1998	WO 9852376 A1	19-11-1998
		AU 738573 B2	20-09-2001
		AU 2895997 A	08-12-1998
		EP 1008269 A1	14-06-2000
		JP 2001525135 T	04-12-2001
		NO 995452 A	08-11-1999
WO 9957826 A	11-11-1999	AU 3826499 A	23-11-1999
		WO 9957826 A1	11-11-1999
		EP 1080555 A1	07-03-2001
EP 0767594 A	09-04-1997	FI 954705 A	04-04-1997
		EP 0767594 A2	09-04-1997
		US 6108553 A	22-08-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

BNSDOCID: <EP_____1073216A3_I_>